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(54) Displays

(57) An electro-optic display device comprises a display screen and e.g. an LCD panel, back-lit by reflected light from an arrangement comprising a set 11-16; 17-22, of partially-reflective, partially-transmissive optical devices positioned in a line-of-sight arrangement with one another and elements 5, 6 or 7, 8 or 9 producing a beam of light which is incident on one of the devices 11 or 17. The devices 11-16; 17-22 may be flat or parabolic mirrors having different reflectivity characteristics to derive uniform light intensity from each mirror. A colour filter 23 may be provided between the mirrors and the panel 4 and a matt black screen 10 cuts off direct light from source 5. Instead of the two sets of mirrors 11-16; 17-22 shown, a single set, a number of single sets or a number of two sets of mirrors may be provided.

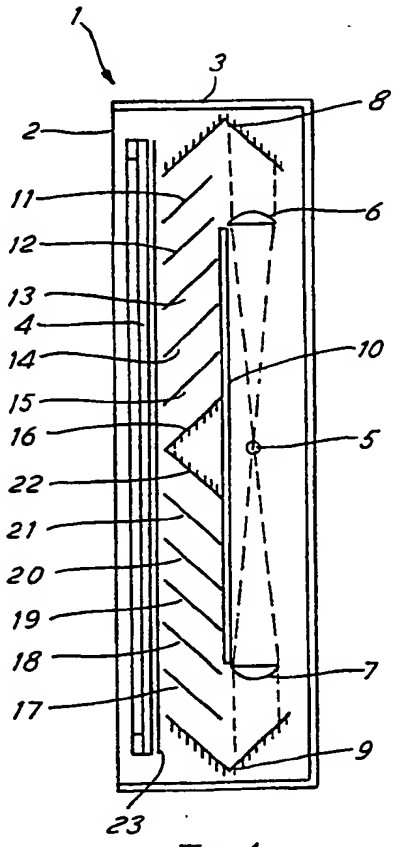

FIG.1

At least one drawing originally filed was informal and the print repoduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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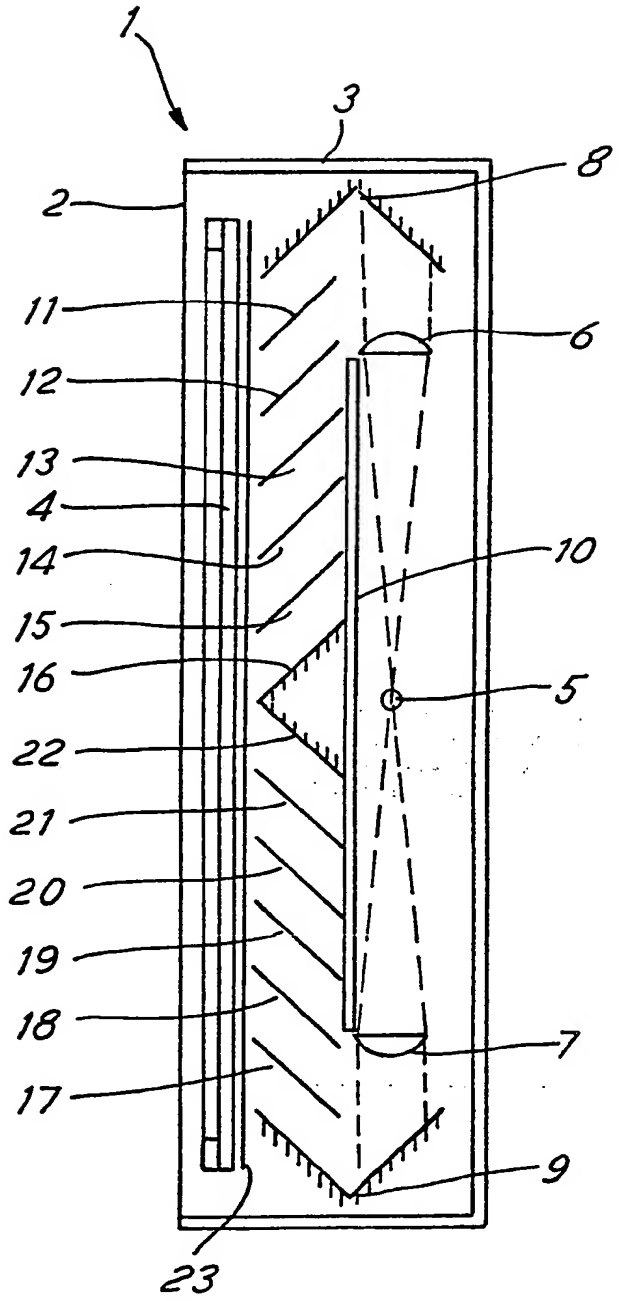

FIG. 1

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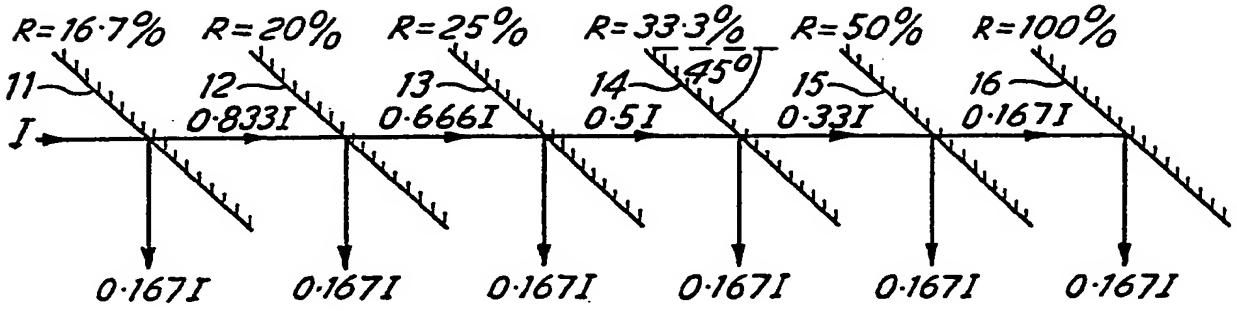

FIG. 2

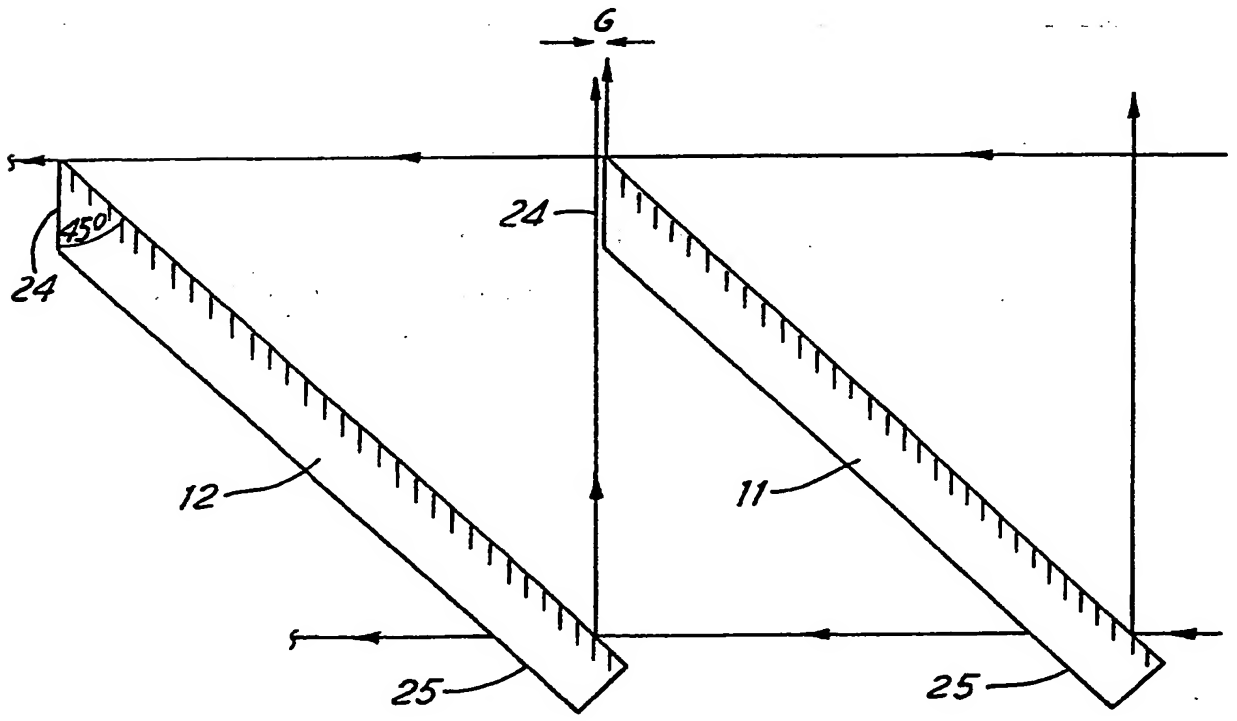

FIG. 3

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DISPLAYS

The present invention relates to a display, especially but not solely a liquid crystal display, which incorporates collimated back lighting.

Liquid crystal displays have a limited viewing angle and low contrast. Such characteristics are particularly disadvantageous when attempting to produce a large area (i.e. a high number of pixels) display panel capable of displaying a complex image rather than, for example, an image of one or a few digits. To overcome the above limitations it is usually necessary to back-illuminate the display with collimated light and employ a diffusing front screen to scatter the light over large viewing angles. This also improves contrast since all light now passes normally through the liquid crystal material.

The present invention provides an electro-optic display device having means to effect collimated back-lighting for a display screen, the back-lighting means comprising a set of partially-reflective, partially-transmissive optical devices positioned in a line-of-sight arrangement with one another and located to reflect light towards the screen, and means to produce a beam of light incident on one of the optical devices in the direction of the said line.

In this way, a liquid crystal display can be provided with effective, uniform back-lighting.

Preferably, the optical devices in a set have different reflectivity characteristics, advantageously the devices being arranged according to the associated reflectivity characteristics such that there is a constant light intensity reflected at each optical device.

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Preferably, an optical device comprises a planar surface on which the light beam is incident; for example, an optical device may comprise a part-silvered flat mirror. Alternatively an optical device may comprise a parabolic surface on which the light beam is incident.

Preferably, the optical devices in a set are inclined at substantially the same angle, advantageously 45^{o}, to the screen. Alternatively, the optical devices may be inclined at different angles to the screen, optionally with the spacing between adjacent devices varying along the line.

Preferably an optical device has a bevelled edge adjacent and parallel to the plane of the screen, to provide substantially continuous illumination of the screen. Preferably the bevelled edge has an interior angle of substantially $(90-\alpha)$, where α is the angle at which an optical device is inclined with respect to the screen.

Preferably, the light production means comprises a point light source, for example a tungsten/halogen lamp.

In order that the invention may more readily be understood, a description is now given, by way of example only, reference being made to the accompanying drawings, in which:-

Figure 1 is a schematic side view of part of a display embodying the present invention;

Figure 2 shows the reflectivity characteristics of some of the mirrors in the display of Figure 1; and

Figure 3 is a detail of the mirrors of the display of Figure 1.

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Liquid crystal display 1, shown in Figure 1, has a diffusing screen 2 at the front of a housing 3 which contains a panel 4 formed of selectively settable liquid crystal cells each representing a pixel of the display. Details of the panel 4 itself are not shown or described because they are not pertinent to the present invention.

Panel 4 is illuminated from behind uniformly and continuously over its area. In order to achieve this, a point source tungsten/halogen lamp 5 is located intermediate, and at the focal planes of, two elongate aspheric Fresnel lens 6 and 7 which cause a parallel light beam to fall onto the right-angled pairs of mirrors 8 and 9 respectively. A matt black screen 10 shields panel 4 from receiving light directly from lamp 5.

The pair of mirrors 8 directs a beam of light onto a part-silvered mirror 11 which is inclined at 45^{o} to the panel 4, such that a proportion of the incident beam is reflected onto the back of panel 4, while the remainder (ignoring any absorption losses) is transmitted through mirror 11 and is incident on the next mirror 12. Again, some of the light incident on mirror 12 is reflected towards the back of panel 4 while the remainder passes through towards mirror 13, this procedure being repeated at mirrors 14 and 15, mirror 16 is fully-silvered such that all the light incident on it is reflected towards panel 4.

As shown in Figure 2, mirrors 11 to 16 have different reflectivity characteristics, the specific values being chosen in order that the intensity of the light beam reflected towards

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the panel 4 by each mirror is constant, being 0.167 I_1 where I_1 is the intensity of the light beam incident on mirror 11.

Likewise, a set of mirrors 17 to 22 are provided, with reflectivity characteristics the same as mirrors 11 to 16 respectively, in order to produce six light beams, each of intensity 0.167 I_2 incident on the back panel 4, where I_2 is the intensity of light directed onto mirror 17. As I_1 is effectively the same as I_2, uniform and constant illumination of panel 4 is provided.

A colour filter 23 may be provided intermediate the mirrors 11 to 22 and panel 4.

Each of the mirrors 11 to 22 has a bevelled edge 24 set at 45^{o} on a lateral face adjacent and parallel to the panel 4, in order to eliminate any discontinuity in the illumination of panel 4. Such bevelling may be achieved by appropriate polishing, and minimises or prevents the gap G between mirrors arising from their finite width, typically about 1mm. The internal angle of the bevel may be reduced to a value below 45^{o} in order to further improve this effect. Alternatively, plastic particle membranes, less than 100 m thick, may be used to reduce this gap.

Each of the mirrors 11 to 22 has an anti-reflection coating 25 on its reverse face in order to minimise losses.

Display 1 can be modified by replacing lamp 5 and lenses 6, 7 with a light source of elongate form (for example a tubular fluorescent or incandescent lamp, or a number of point sources in a line) and appropriate lenses. In another modification, a

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display has only a single set of inclined mirrors (e.g. corresponding to mirrors 11 to 16), as distinct from display 1 which has two sets of mirrors (namely 11 to 16 and 17 to 22). In another modification, a display has a number of single sets of mirrors, or has a number of two sets of mirrors, or has a combination of single sets and two sets.

The above-described arrangement provides a liquid crystal display which is uniformly backlit, yet is thin (typically 10cm thick) as compared to conventional constructions. Moreover the display can be cheaply constructed, enables colour filters to be positioned outside the liquid crystal cell and utilizes a single light source thereby obviating problems of matching luminosities.

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CLAIMS

1. An electro-optic display device having means to effect collimated back-lighting for a display screen, the back-lighting means comprising a set of partially-reflective, partially-transmissive optical devices positioned in a line-of-sight arrangement with one another and located to reflect light towards the screen, and means to produce a beam of light incident on one of the optical devices in the direction of the said line.

2. An electro-optic display device according to Claim 1 wherein the optical devices in a set have different reflectivity characteristics.

3. An electro-optic display device according to Claim 2 wherein the optical devices are arranged according to the associated reflectivity characteristics such that there is a constant light intensity reflected at each optical device.

4. An electro-optic display device according to any one of the preceding claims wherein an optical device comprises a planar surface on which the light beam is incident.

5. An electro-optic display device according to Claim 4 wherein an optical device comprises a part-silvered flat mirror.

6. An electro-optic display device according to any one of Claims 1 to 3 wherein an optical device comprises a parabolic surface on which the light beam is incident.

7. An electro-optic display device according to any one of the

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preceding claims wherein the optical devices in a set are inclined at substantially the same angle to the screen.

8. An electro-optic display device according to Claim 7 wherein said same angle is 45^{o}.

9. An electro-optic display device according to any one of Claims 1 to 6 wherein the optical devices in a set are inclined at different angles to the screen.

10. An electro-optic display device according to Claim 9 wherein the spacing between adjacent optical devices varies along the said line.

11. An electro-optic display device according to any one of the preceding claims wherein an optical device has a bevelled edge adjacent and parallel to the plane of the screen.

12. An electro-optic display device according to Claim 11 wherein the bevelled edge has an interior angle of substantially $(90-\alpha)$, where α is the angle at which an optical device is inclined with respect to the screen.

13. An electro-optic display device according to any one of the preceding claims wherein the light production means comprises a point light source.

14. An electro-optic display device according to Claim 13 wherein the point light source comprises a tungsten/halogen lamp.

15. An electro-optic display device substantially as hereinbefore described with respect to any one of the Figures in the accompanying drawings.

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